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RECENT CHANGES IN THE EPIDEMIOLOGY OF MALARIA RELATING TO HUMAN--ETC(U)

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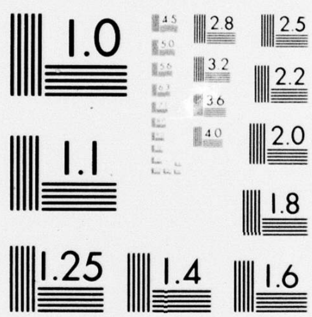

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Recent Changes in the Epidemiology of Malaria Relating to Human Ecology[1]

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ABSTRACT (12) 9p.

The major factors of human ecology which influence or are likely to influence the spread of malaria are the growth of cities and towns (urbanization), transport and population movements, agricultural and engineering developments (irrigation and building of dams), changes in customs and habits and the introduction of a vector species into an unexploited habitat. Recent examples of changes in the epidemiology of malaria which are related to these factors are described. Prospects for the future control of malaria are briefly discussed.

Changes in malaria transmission related to spraying practices which have produced insecticide resistance, refractory behavior of a mosquito vector towards the insecticide and emergence of unsuspected or secondary vector species not controlled by practices directed towards the primary vector are considered beyond the scope of this review. The problem of drug-resistance is likewise an extremely important one which has been recently reviewed by others.

The accepted patterns for the transmission of malaria are changing in many areas of the world. Mosquitoes which were formerly considered to be vectors can no longer be found in certain regions or cannot be recognized in view of new concepts on the identification of species groups. In this context, *Anopheles gambiae* Giles is now known to consist of 6 species, 4 of which are referred to as *gambiae* species A, B, C and D; each of which has a distinct ecology. Cities or even nations which thought they had malaria well under control find themselves in the midst of epidemics of this disease. The promise which DDT and other persistent pesticides held forth have largely disappeared. Physicians and health authorities now find it difficult to treat cases of falciparum malaria in Asia and portions of the New World tropics due to the presence of drug-resistant parasite strains.

The purpose of this review is to re-emphasize that the epidemiology of human malaria is in a constant state of change which is closely related to the alteration of the natural environment by man. With the marked increase in human population over the past few decades, and increasing exploitation of a variety of habitats for the growth of urban centers and development of agricultural resources, it is not unexpected that such changes have occurred and will occur at a rapidly increasing pace.

It is not within the scope of this review to discuss these problems and changes in any depth, but it is hoped that the presentation of some recent problems in malariology will stimulate new interest in understanding and appreciating an old disease.

Attempts have been made by specialists to categorize these recent changes. The most useful classification has been made by Smith (1975) who recognizes 4 broad groups of factors which

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influence or are likely to influence patterns of disease. These factors are often interrelated as this review points out, but they can be divided into: (1) the growth of towns and cities (urbanization), (2) transport and population movements, (3) agricultural and engineering developments (irrigation and building of dams), and (4) changes in customs and habits. To these might be added a 5th factor, the introduction of a vector species to an unexploited habitat.

Urbanization

Two recent examples will be cited to document the increase of malaria in large tropical cities; the first involves Karachi in Pakistan and the second involves Kinshasa in the Republic of Zaire.

Since 1941, Karachi has experienced considerable population growth due to immigration and natural growth. From a population of 387,000 in 1941, the metropolis grew to an estimated 3.8 million in 1968. The climate of Karachi is hot with minimal rainfall (less than 2.5 cm of rain had fallen during the first 8 mo of 1968) and the city is surrounded by semi-desert. Under these conditions, a rapid increase in malaria occurred from 1966 to the middle of 1968 when it was estimated that 10-20% of the population or 400,000-800,000 people had malaria infections (Carmichael 1972).

The vector was identifed as *An. stephensi* Liston on the basis of epidemiological investigations which found sporozoite rates as high as 1.2% (Communicable Disease Center 1968). Anopheline larvae were found breeding throughout the city in surface water such as pools from leaks in the piped public water system, in household water storage containers and in effluents from sewage treatment plants. This water all originated from water piped into the city, sometimes as far away as 100 miles from the city.

This epidemic was clearly attributed to problems in the management of waste water which were beyond the control of municipal agencies at the time. Typical of this was that sewage effluent was discharged into adjoining dry river beds where *An. stephensi* breeding was abundant. Recommendations for control were made by a U.S. team of public health investigators which were primarily predicated upon source reduction procedures.

During the quarter of a century between 1948 and 1975, Kinshasa (formerly Leopoldville) has experienced a similar population growth. In 1948, the population was 126,000 and by 1975, it had increased 10-fold to 1.3 million. Prior to independence in 1960, malaria was well under control in this city where an active control program was in progress and waste water conducted away in well-constructed drains. Most new cases of malaria were attributed to introductions from the surrounding countryside where crops were grown for the city markets and movement of infected citizens along the Zaire (Congo) River.

In the absence of epidemiological data from Kinshasa in the post-independence period, aside from reports of medical officials that malaria was becoming more prevalent, a field study was conducted in Kinshasa during 1973 (R.A. Ward, C.L. Diggs, J.C. Burke and W.A. Reid, unpublished data). Children were observed with falciparum infections at an outpatient clinic of a hospital and visits made to their homes to determine possible sources of infection. In virtually all cases, *An. gambiae* (probably species A), was found breeding anywhere from a few to several hundred meters from a patient's home. Larvae occurred in all types of water, with the exception of fast-flowing ditches. Especially impressive was the observation that *An. gambiae* larvae were extremely abundant in highly polluted water containing household wastes. It was estimated that at the end of the rainy season in July 1973, the malaria infection rate approached 25% in the more recently developed areas of the city which lacked sanitary waste or storm water disposal facilities. Since *An. gambiae* larval breeding appeared to be so restricted to man-made habitats, it appeared reasonable that control could be readily initiated.

The process of urbanization may at times produce such unfavorable conditions, that malaria may disappear with minimal control activities. This was apparently a major factor in the disappearance of malaria from Great Britain in the early portion of the 20th century. In the Netherlands, the sharp reduction of malaria incidence since 1947 and disappearance by 1958, it attributed to a decline in the population of *An. atroparvus* van Thiel in the province of North Holland and the northeast Polder as a result of a marked decrease in the number of pig sties and stables where the females can feed and rest. Associated with insecticidal treatment, breeding places were found to be increasingly polluted with anionic detergents which are toxic to anopheline larvae at a concentration of 2 ppm (Seventer 1969).

Agricultural and Engineering Developments

Agricultural practices are known to have a profound influence upon the epidemiology of malaria. A review of the overall problem of the effects of irrigation on mosquito populations and mosquito-borne diseases in man was made by Surtees (1970). In virtually all instances where land is developed in the tropics from forests, or even plains which are subject to irrigation, serious malaria problems develop within a few years unless careful advance planning has occurred.

The increased significance of *An. balabacensis* Baisas as an important vector of malaria in Southeast Asia appears directly related to the destruction of tropical evergreen forests in the forested foothills of countries such as Thailand. When land is cleared for crops such as tapioca, an interface is usually left between freshly cleared land and the higher vegetated hills which are unsuitable for agriculture. This provides an ideal breeding and resting site for *An. balabacensis* which increases in numbers under such conditions. Its marked preference for human blood meals; its feeding behavior indoors and preference to rest outdoors in vegetation after a meal; its high level of susceptibility to infection with falciparum malaria and its great longevity make this species one of the most efficient malaria vectors known. Control of malaria under such conditions is extremely difficult, especially when drug-resistant strains of falciparum malaria are associated with this vector (Scanlon and Sandhinand 1965). Retrospective studies in some of the above areas of Thailand indicate that as the land becomes more intensely cultivated, and the hilltop remnants of forest are removed for firewood, the breeding sites of some of the larval *An. balabacensis* are removed with a resulting reduction in the adult population. Some larval breeding can still occur as it is a fairly adaptable species whose larvae can develop in small ground depressions or larger bodies of standing water such as rain-filled pits dug for the mining of sapphires.

The construction of great dams to form large reservoir lakes in Africa has had an influence on the incidences of diseases transmitted by aquatic molluscs and insects with aquatic larvae. Akosombo Lake was formed by the construction of a dam on the Black Volta in Ghana from 1964-1968. Its formation resulted in much increased production of the vector species *An. gambiae*, *An. funestus* Giles and *An. hargreavesi* Evans (Deschiens 1972). Similar problems have been predicted along the shores of Lake Nasser which was formed by the high dam at Aswan on the Nile. This entire problem is carefully analyzed by Stanley and Alpers (1975) in a recent book, "Man-made Lakes and Human Health".

Fortunately, through careful management, the construction of dams may also have a positive effect by decreasing the incidence of malaria vectors. Along the upper course of the Rio Parana in Brazil, extensive flooding occurred until various dams on the tributaries of the Parana and the main river were completed in 1968 and regulated the flow. After this period, marked decreases in abundance of *An. darlingi* Root and *An. albitarsis* Lynch Arribalzaga were noted once the dams controlled the floods (Consolim and Galvão 1973).

The Kunduz Valley of northern Afghanistan affords an excellent example of a complete change in malaria epidemiology in a desert-steppe habitat. Approximately 15 years ago, prior to the introduction of irrigation in the Kunduz Valley, *An. superpictus* Grassi was considered to be the most important vector species in this region. Its larvae lived in the only source of suitable water; small seepages of fairly clean water at the base of small hills. A number of other anopheline species were present but were considered to be of little or no significance in malaria transmission. Following the initiation of irrigation, large-scale agricultural schemes were developed for the valley with the subsequent planting of rice, cotton and melons as the main crops. Associated with this was an increase in both the human and cattle population. *Anopheles superpictus* disappeared from the Kunduz Valley as the natural breeding sites became contaminated from the activity of cattle and men. New larval habitats were created by the standing water in rice fields, overflow from irrigation ditches and polluted seepages. These provided ideal breeding conditions for *An. pulcherrimus* Theobald early in the malaria transmission season and for *An. hyrcanus* (Pallas) near the end of the transmission season. The incidence of vivax malaria rose from 5 to 25% in some villages over a period of 3 years as a consequence of these vectorial changes. At the present time, malaria control is difficult because *An. hyrcanus* is resistant to DDT and *An. pulcherrimus*, although susceptible, avoids surfaces treated with DDT. Transmission is further facilitated by the habits of the local inhabitants. During the melon-harvesting season, the men sleep in the fields to prevent theft of the crop and during the hot summer months, most of the villagers sleep outdoors in courtyards which are in close proximity to cattle sheds which serve as a further attractant for mosquitoes. Consequently, no protective measures are taken by the village inhabitants against mosquitoes (Buck et al. 1972).

Transport and Population Movements

Increases in malaria related to these factors are more difficult to analyze due to the length of time that is required for changes of this type to become evident and the fact that entomologists only become aware of these situations *de post facto*, with the obvious exception of malaria related to armed conflict.

The highlands region of New Guinea affords an excellent example of a rapidly changing pattern of malaria epidemiology. The inhabitants, who for the most part live in small villages or hamlets along valleys or on the tops of mountain ridges at an elevation of 1,300 to 2,500 m, had little contact with civilization until the 1930's or for some not until the 1950's. Most of this early contact was through administrative officials, mission workers and gold miners. The traditional routes for the entry of malaria into the relatively malaria-free highlands were through war parties, often cannibalistic, and trade journeys down into the hot, humid malarious areas of the Markham and Ramy valleys. Other cases of malaria were acquired during visits to the rich alluvial plains along the south bank of the Ramu River while cultivating gardens. Females usually exhibited higher infection rates than males as they traditionally devoted more time to gardening than males.

With the pacification of the highlands region and greater influence of missionaries in the post World War II period, the region rapidly became exposed to malaria through a variety of routes. These included the building of access roads and the creation of new labor markets. Numerous infection reservoirs were introduced by coastal workers who came from malarious lowland areas. By far the greatest source of new malaria cases came from highland laborers who worked on coastal rubber, coconut and cocoa plantations for relatively long periods of time before returning home. With the improvement of roads, a much greater interchange of people occurred. As an example, before a road from the Markham Valley was improved in 1968, the average number of vehicles passing through into the highlands was 15 daily; after improvement, 87 daily. Parasitological surveys made in 1965 indicated that 3.1% of passengers in the vehicles entering the highlands had positive malaria smears. Thus it is easy to determine the mechanism of rapid dissemination of malaria into this region.

The earthmoving associated with building houses and roads has created an abundance of new breeding sites for *Anopheles* species. In addition, the vehicles may also have served as a source of infected mosquitoes.

Early mosquito surveys (1945-50) indicated that *An. farauti* Lavaran was the most abundant vector species in the highlands of New Guinea. Although larvae were common around some of the towns, adults were relatively rare and the conditions of "anophelism sans malaria" prevailed in many areas. Malariometic data is scarce from the early period, but a survey in the Wahgi Valley during 1934-35 found 3.3% of children with palpable spleens. Surveys made in 1964, preparatory to initiation of a malaria control program revealed that both *An. puctulatus* Dönitz and *farauti* were present in houses, the former species in greater abundance. Larvae of both species were plentiful and there was a significant increase in the prevalence of adults as compared with earlier surveys. There was a corresponding increase in malaria in the Wahgi Valley in 1956 with as high as 78% of the blood films positive for malaria during an epidemic.

Since 1966, when an extensive program of residual spraying was initiated and a mass chemotherapy program developed, the average parasite incidence rate dropped from 13.8% to 0.3% by 1969. A small residual amount persisted due to the uninterrupted flow of traffic through the infected Markham Valley (Radford et al. 1976).

Mosquitoes are regularly imported into the Termez area of Uzbekistan, U.S.S.R. by river transport on the Amudarya between various Soviet and Afghanistan ports. *Anopheles pulcherrimus* Theobald, an important malaria vector of northern Afghanistan, is collected with high frequency from all types of vessels. This species is found in greatest numbers aboard during July and August when transmission is at a maximum level. Iadhieva and Abdullaev (1975) believe that foci of malaria are introduced annually into Termez by this mechanism.

During the past year, evidence was presented that *An. barbirostris* Van der Wulp, an Oriental vector, became established on the island of Guam (Ward et al. 1976). This species was probably introduced via cargo vessels or aircraft refueling on Guam en route from southeast Asia to the United States.

Changes in Customs and Habits

There are numerous instances where the acquisition of malaria is closely associated with special conditions of making a livelihood which have been altered due to economic or political considerations. Several recent examples of malaria transmission related to social conditions are described below.

A detailed analysis of the epidemiology of malaria in Trinidad in the 25 years from 1940-1964 indicates that cultural patterns of land use, migration and settlement and changes in mosquito abatement practices are all important variables for an understanding of the malaria picture in Trinidad (Fonaroff 1968). The subtile relationships between the association of *An. bellator* (Dyar and Knab), its bromeliad plant hosts, cacao growing with the associated lowland Bocare tree (*Erythrina glauca*) and the behavior of the East Indian cacao farmers all create the most complex pattern of malaria epidemiology known. This is probably one of the best studied examples of man-made malaria and serves to emphasize the malariological problems associated with artificial or cultivated tropical forests (Downs and Pittendrigh 1949).

During the period between 1947 and 1970, there was a significant reduction in the numbers of adult *An. atroparvus* Van Thiel found in animal sheds in southern Moravia, Czechoslovakia. Minar and Rosicky (1975) state that this is due to the fact that the large sheds which were erected for cattle or pig sties during collectivization proved to be less favorable resting sites than the smaller shelters which existed prior to the formation of collectives.

In West Malaysia and Singapore, the fruit of the durian is extremely popular. In order to prevent theft of the fruit, plantation owners stay up at night to collect the ripe fruits as soon as they fall. This has resulted in an increase in the incidence of falciparum malaria among people living and working in Kuala Lumpur, who are bitten by infected anophelines in their plantations at night from June to September (Ponnampalam 1975).

Introduction of Vector Species into New Habitats

The accidental introduction of a malaria vector into a new environment where it can survive is often the key factor in a change in the epidemiology of malaria. The situation in Brazil in which *An. gambiae* from Africa became established, its role in malaria transmission during the 1940's and its subsequent eradication has been well documented (Soper and Wilson 1943). A retrospective review of the malaria epidemic which occurred on the island of Barbados from 1927-1929 serves to further document this point.

Prior to 1927, there was no evidence that the principal malaria vector of the Caribbean area, *An. albimanus* Wiedemann, existed on Barbados, or if it did, it was not present on the leeward side of the island. During the spring of 1927, the normal dry season did not occur and small surface bodies of water persisted for many months. Anopheline breeding suddenly occurred in abundance along the western and southwestern coastal region during the spring and early summer. By the time *An. albimanus* was identified, more than 300 cases of malaria had been reported during October 1927. Medical records indicated that malaria had been regularly introduced into the island since 1920 by returning migrant male workers. Since no new transmission to other family members occurred until 1927, it was surmised that a vector was not present earlier. Fonaroff (1966) believes that a successful introduction of *An. albimanus* happened as a consequences of the abnormally favorable environment available in the spring of 1927. This introduction was most likely through the agency of coastal-plying vessels rather than wind dispersal due to the island's easterly location in respect to the other Antilles and the prevailing wind direction of the northeast trade winds.

Prospects for the Future

From the developments of the recent past, it can be assumed that malaria will continue to be a serious disease in the future. The increase in urbanization and development of land for agriculture and other purposes appear to present the most potential problems for the future. Other authors have stressed the role of intercontinental flight in transporting agents of infection and their arthropod hosts as an area for future concern, but this seems to be less important for malaria than for arbovirus diseases such as yellow fever and the dengue fevers.

In a literature search which was made during the preparation of this paper, little indication was found that many tropical cities could manage the vector-disease problems which have been proliferating at a rapid rate. Generally, those metropolitan regions which showed the highest rates of growth during the past 25 years have the most public health problems. A number of these situations (i.e., filariasis in Rangoon, malaria in Karachi and Kinshasa) have emerged due to the inability of the municipalities and their adjacent suburbs to handle the problem of sewage and industrial wastes or excessive rainfall. The creation of numerous small bodies of water, rich in organic matter, provides an ideal breeding site for a number of mosquito species (i.e., *Aedes aegypti* (L.), *Culex quinquefasciatus* Say (=*C. fatigans* Wiedemann), *C. tritaeniorhynchus* Giles, *Anopheles gambiae* and *An. stephensi*) and the ready availability of human hosts in high densities permits the rapid development of large mosquito populations. Consequently, it is not unexpected that epidemics of disease can occur over a very short period of time.

The solution of future problems of urban malaria appears to be one of proper urban planning. Entomologists and public health authorities should participate in the early stages of development. Whenever economically feasible, storm drains and sewers should be installed in areas where construction will occur. This is a far more practical procedure than to attempt to rebuild these systems 20 years after a new area of a city has developed while simultaneously carrying out a costly vector control program.

In contrast to the urban situation, there now appears to be a greater awareness in conducting large-scale agricultural and water management projects in respect to health problems than has occurred in the past. Examples of such advance planning are as follows:

(1) Bayano River Project, Republic of Panama. – Ecological studies are being conducted on a large hydroelectric river impoundment in Panama by the Gorgas Memorial Laboratory. Special emphasis is being placed upon the impact of this project on arbovirus disease transmission cycles and the ecology of anopheline mosquitoes. These studies started prior to the initiation of the project in 1976 and will continue as a large lake is being formed. (P. Galindo, personal communication).

(2) Atlantic Pacific Interoceanic Canal Study Commission. – Medical ecology studies were conducted from 1966-1968 by the U.S. Army Medical Department on potential canal routes in Panama and northern Colombia to identify actual and potential disease problems which might be encountered during the construction of a new Atlantic-Pacific canal (B.F. Eldridge et al. 1973).

(3) Medical Research Council Project, Kisumu, Kenya. – A long term study on the effects of irrigation on local public health was started in 1970, several years in advance of irrigation. The advisors will devise and put into effect measures which will control the spread of disease once the risks have been assessed. Control measures will be monitored to prevent deleterious effects (Simpson 1975).

It is apparently easier to marshal the necessary resources and personnel (politicians, economists, engineers and scientists) to consider the consequences of these larger developmental projects due to the tremendous economic impact that successful development will have upon one or more nations.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

THE MAJOR FACTORS WHICH INFLUENCE OR ARE LIKELY TO INFLUENCE THE SPREAD OF MALARIA ARE THE GROWTH OF CITIES AND TOWNS URBANIZATION, TRANSPORT AND POPULATION MOVEMENTS, AGRICULTURAL AND ENGINEERING DEVELOPMENTS IRRIGATION AND BUILDING OF DAMS, CHANGES IN CUSTOMS AND HABITS AND THE INTRODUCTION OF A VECTOR SPECIES INTO AN UNEXPLOITED HABITAT. RECENT EXAMPLES OF CHANGES IN THE EPIDEMIOLOGY OF MALARIA WHICH ARE RELATED TO THESE FACTORS ARE DESCRIBED. PROSPECTS FOR THE FUTURE CONTROL OF MALARIA ARE BRIEFLY DISCUSSED.

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CHANGES IN MALARIA TRANSMISSION RELATED TO SPRAYING PRACTICES WHICH HAVE PRODUCED INSECTICIDE RESISTANCE, REFRACTORY BEHAVIOR OF A MOSQUITO VECTOR TOWARDS THE INSECTICIDE AND EMERGENCE OF UNSUSPECTED OR SECONDARY VECTOR SPECIES NOT CONTROLLED BY PRACTICES DIRECTED TOWARDS THE PRIMARY VECTOR ARE CONSIDERED BEYOND THE SCOPE OF THIS REVIEW. THE PROBLEM OF DRUG-RESISTANCE IS LIKEWISE AN EXTREMELY IMPORTANT ONE WHICH HAS BEEN RECENTLY REVIEWED BY OTHERS.

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